PROC. ENTOMOL. SOC. WASH.
93(1), 1991, pp. 16–44

SYSTEMATICS, MORPHOLOGY, BIOLOGY, AND HOST SPECIFICITY OF *NEUROSTROTA GUNNIELLA* (BUSCK) (LEPIDOPTERA: GRACILLARIIDAE), AN AGENT FOR THE BIOLOGICAL CONTROL OF *MIMOSA PIGRA* L.

Donald R. Davis, Richard C. Kassulke,
Ken L. S. Harley, and John D. Gillett

(DRD) Department of Entomology, National Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560; (RCK & KLSH) CSIRO Division of Entomology, Long Pocket Laboratories, Private Bag No. 3, Indooroopilly, Australia 4068; (JDG) Department of Primary Industries and Energy, PO Box 858, Canberra, Australia 2601.

Abstract.—The systematics and morphology of the gracillariid moth, *Neurostrota gunniella* (Busck, 1906), from Mexico are reviewed. The biology and host specificity of this moth were studied in quarantine facilities in Brisbane, Australia. Eggs were usually laid singly on the ventral surface of mature leaves of *Mimosa pigra* L. The first two larval instars were sap-feeding miners in the leaf pinnules. Instars three to eight were tissue-feeding stem borers. Pupation occurred outside the stem within a silken cocoon festooned with frothy globules excreted by the larva.

One hundred species of plants, either closely related to *M. pigra* or of economic or environmental importance, were tested in host specificity studies as part of an assessment of the suitability of *N. gunniella* as a biological control agent for *M. pigra*. The only plants which supported development of *N. gunniella* were the two introduced weeds, *M. pigra* and *M. pudica*, and four Australian *Neptunia* species. Larval mortality was high on the *Neptunia* species. These studies showed that *N. gunniella* would not cause damage to any plant other than the target weed, *M. pigra* in Australia. *N. gunniella* was first released near Darwin, Australia in February, 1989.

Key Words: Lepidoptera biology, Gracillariidae, *Neurostrota, Mimosa pigra,* biological control, host specificity

Mimosa, *Mimosa pigra* L. (Leguminosae), is native to tropical America (Burkart 1948) where it usually occurs as small clumps of multi-stemmed plants growing in seasonally flooded habitats (Fig. 1). It probably entered the Northern Territory of Australia during the 20 years prior to 1891 (Miller & Lonsdale 1987), underwent a population explosion in the late 1970's and now infests 45,000 ha of wetlands (Lonsdale and Segura 1987). Dense to scattered thickets of *M. pigra* cover the floodplains of the Adelaide River, with major infestations on the Finniss, Mary, and East Alligator Rivers (Pitt and Miller 1989, Miller 1982). *M. pigra* is a designated Class "A" noxious weed in the Northern Territory (Noxious Weeds Ordinance 1962), is a serious weed in Thailand (Napompeth 1982) and is spreading in Burma, Laos, Kampuchea, Vietnam, Indonesia and Malaysia (Napompeth, B., pers. comm.). In the Northern Territory it prevents access for irrigation and stock watering, makes livestock mustering difficult and interferes with the use of watercourses for recreation (Miller et al. 1981). On flood plains it out-competes other plants and seriously reduces dry season grazing for cattle and buffaloes. There and in Southeast Asia it occurs as huge, impenetrable, near monospecific thickets.

Two other *Mimosa* species, *M. invisa* Mart. and *M. pudica* L. have been introduced into and become weeds in Australia (Kleinschmidt and Johnson 1977). *M. invisa* is confined to Queensland and *M. pudica* is widespread throughout Queensland, northern New South Wales and the Northern Territory.

A program for biological control of *M. pigra* in Australia was initiated by CSIRO and the Northern Territory Department of Primary Industry and Fisheries in 1979 and extended to Thailand through a program of the Australian Centre for International Agricultural Research (ACIAR) in 1983. In investigations in Mexico, adults of a gracillariid moth *Neurostrota gunniella* (Busck) frequently emerged from tips of *M. pigra* and occasionally from tips of another legume native to Mexico, *Neptunia plena* (L.) Benth. Following preliminary tests in Mexico for specificity to *M. pigra, N. gunniella* was imported into Australia for detailed evaluation in quarantine.

This paper gives details of studies on the systematics and morphology of *N. gunniella* conducted at the Smithsonian Institution as well as studies of its biology and host specificity carried out by the Division of Entomology, CSIRO, Australia.

Systematics and Morphology

Neurostrota gunniella (Busck)

Gracilaria [sic] (*Dialectica*) *gunniella* Busck, 1906: 731.

Acrocercops gunniella (Busck) Meyrick, 1912a: 16, 1912b: 44. Barnes and McDunnough, 1917: 188.

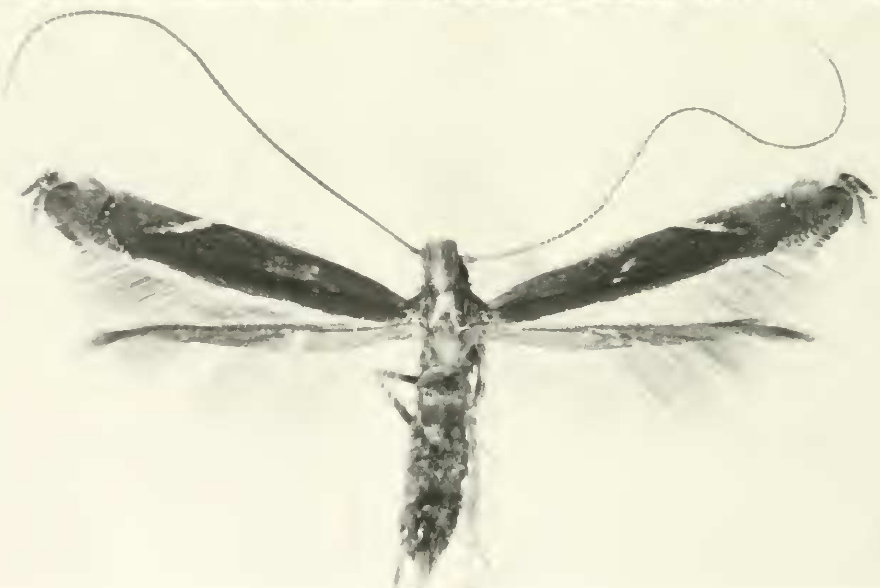
Neurostrota gunniella (Busck) Ely, 1918: 38, 41, 68. McDunnough, 1939: 97. Vari, 1961: 41. Davis, 1983: 9; 1984: 26.

Neurostrata [sic] *gunniella* (Busck) Ely, 1918: 41. Busck, 1934: 179.

Adult (Fig. 2).—Forewing length: ♂, 3.3–4.4 mm; ♀, 3.2–4.6 mm. Small moth with dark coppery brown forewing possessing a single, oblique, cream white stria at distal third of costa and hind margin bordered with cream. Male valva rhombiform, simple; seventh abdominal segment with a single pair of elongate hair pencils and a more basal tuft of short, spatulate sex scales. Female bursa with a pair of diamond shaped signa.

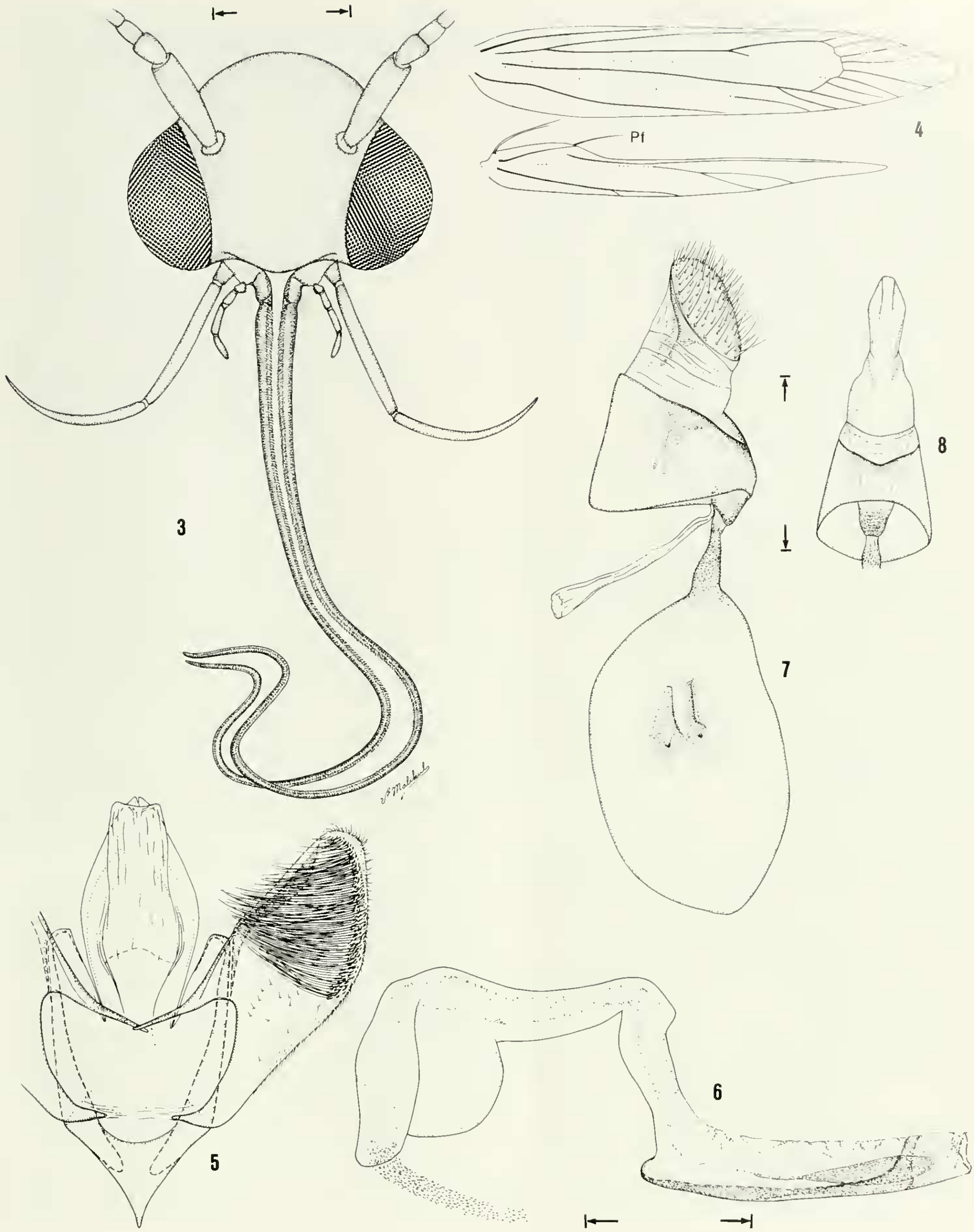
Head (Fig. 3): Vestiture smooth, scales curving down over frons; vertex cream to pale buff at middle, becoming darker brown laterally; a patch of brownish fuscous scales at anterior rim of eye below antenna; lower frons mostly silvery white. Antenna ca. 1.2× length of forewing, covered with dark brown scales dorsally and dull white ventrally. Ocellus absent. Interocular index ca. 1.1. Mandible absent. Maxillary palpus moderately long, four segmented, silvery white dorsally, grayish brown ventrally. Haustellum elongate, over 2× length of labial palpus, coiled in repose. Labial palpus slender, elongate, over 2× vertical diameter of eye, curved dorsally; vestiture silvery white dorsally, grayish brown ventrally and laterally.

Thorax: Pronotum dark coppery brown with a broad cream to pale buff median stripe; venter dark brown laterally, silvery white over coxa. Wing venation as shown in Fig. 4. Female frenulum consisting of two bristles (Figs. 9–11), male of one bristle, with basal fusion of ca. 5–6 setae (Figs. 12–14). Both sexes with a secondary pseudofrenulum arising near termination of Sc and consisting of usually 3–4 piliform scales tightly overlapping (Figs. 9, 15–18). Pseudofrenulum coupling with a row of stiff, specialized scales located along the ventral hind margin in the anal area of the forewing (Figs. 19, 20). Forewing mostly dark coppery brown



2

Figs. 1, 2. 1, A dense concentration of *Mimosa pigra* near Acapulco, Mexico. 2, *Neurostrota gunniella*, adult ♀, forewing length 4.2 mm.



Figs. 3–8. *Neurostrota gunniella.* 3, Head, frontal view (0.25 mm). 4, Wing venation, pf = pseudofrenulum. 5, Male genitalia, ventral view (0.25 mm). 6, Aedoeagus. 7, Female genitalia, lateral view (0.5 mm). 8, Ventral view. (Scale lengths in parentheses.)

with a single, cream-white stria extending obliquely from distal third of costa about half the distance to tornus; a single, narrow, silver fascia transversing subapex; fringe with a pair of dark brown striae curving around apex; hind margin bordered with cream to tornus; fringe along hind margin uniformly dark gray. Hindwing uniformly dark gray. Legs dark brownish fuscous with apex of tibia and most of tarsal segments banded with cream; tarsi of hindleg mostly dull white to pale buff.

Abdomen: Dark brownish fuscous dorsally, mostly cream to white ventrally, with 5 slender, dark fuscous, oblique bands laterally across segments A2–6. Male with a single pair of elongate hair pencils and a more basal tuft of short, spatulate sex scales lateral on A7. A7 greatly reduced. Tergite 8 enlarged, well defined, hoodlike, extending caudad of lateral sex scaling on A7.

Male genitalia (Figs. 5, 6): Uncus absent. Vinculum, triangular with broad, lateral projections dorsad to base of valva. Valva rhombiform, with outer margin relatively straight and oblique. Aedoeagus relatively simple, lightly sclerotized, equalling length of valva; cornuti absent; phallobase 1.5× length of aedoeagus.

Female genitalia (Figs. 7, 8): Anterior and posterior apophyses equally developed, short. Ductus bursae shorter than length of corpus bursae; seminal duct arising midway along ductus. Corpus bursae well developed, ovoid, with a pair of roughly diamond-shaped signa.

Egg (Figs. 27–31).—Elongate-ovoid, with a minutely dimpled chorion; average length 0.357 mm, width 0.164 mm (n = 20). Micropyle with 3–6 oval rings clustered around a minute central depression.

Larva (Figs. 32–60, 63–70).—Hypermetamorphic; first two instars with highly modified, depressed body for sap-feeding in leaf pinnules; maximum length, 1.2 mm. Remaining six instars of typical caterpillar form with cylindrical body, boring in stems of host. Length of largest larva 8.0 mm; maximum body width 1 mm; maximum head width 0.54 mm; body color instars 1–7 cream, instar 8 dark blue-green, later reverting to cream.

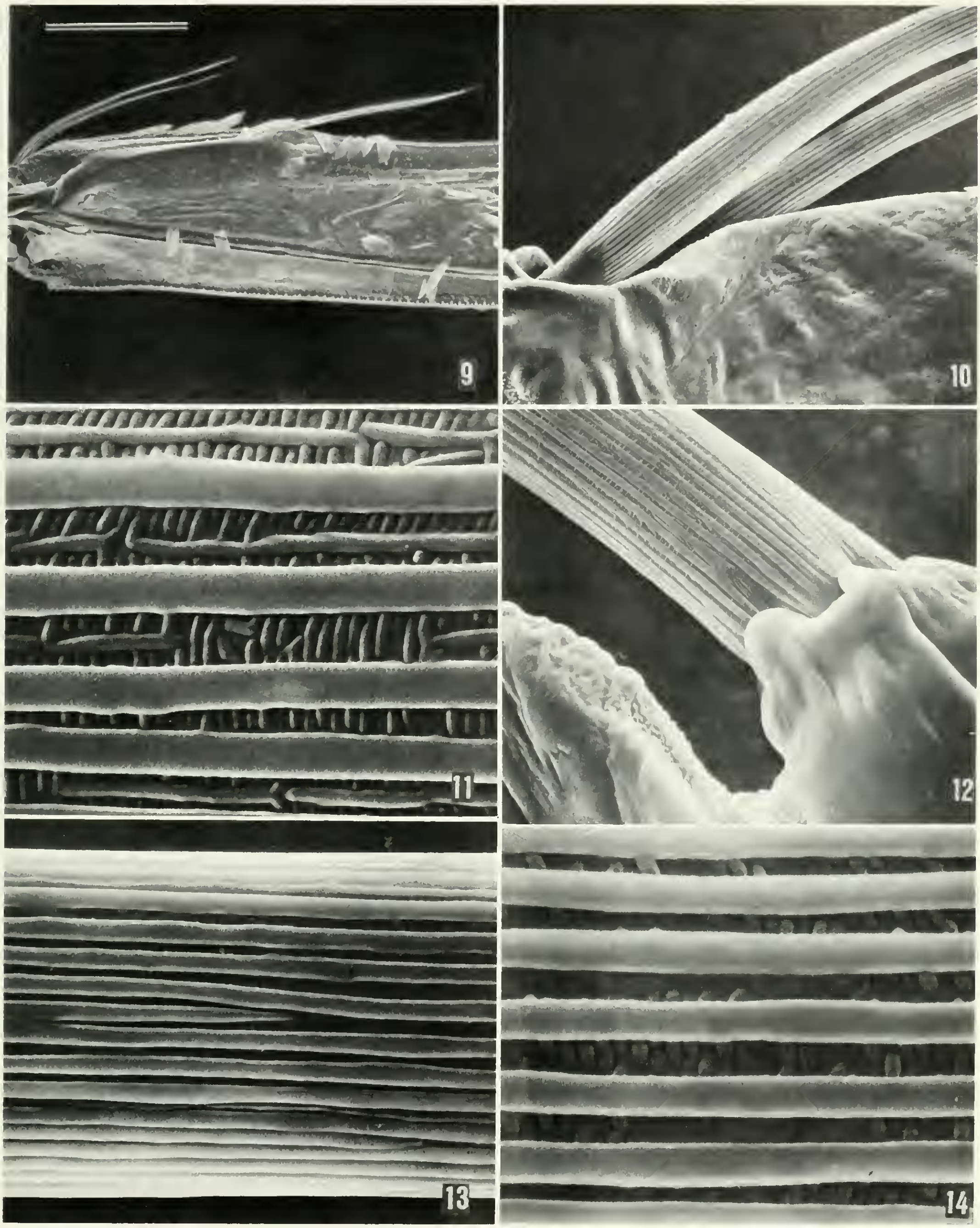
Sap-feeding Instars

Head: Greatly depressed, triangular (Figs. 32, 39). Most setae lost or reduced; dorsal cranium with only two small pairs of setae preserved, P2 near basal lateral margin and L1 above median (third) stemma. Labrum (Fig. 33) reduced, 0.64 the width of labial lobe, deeply clefted about 0.25 its length; only one pair of setae preserved; venter of labrum with dense concentration of short epipharyngeal spines (Fig. 37). Mandibles large, greatly flattened, with three primary cusps dorsally; innermost cusp broad with serrated margin; outermost cusp with a dorsal groove and a fourth, shorter cusp arising ventrad. Labial lobe (Figs. 34, 35) with anterior margin slightly depressed at middle; anterior margin and dorsal surface densely covered with short hypophyrangeal spines (Fig. 38) similar to epipharynx; spinneret vestigial, reduced to a minute, flushed opening ca. 0.86 μm in diameter. Ventral cranium with only a single pair of substemmatal setae (SS3?). Maxillary and labial palpi absent. Antenna reduced, with three relatively stout sensilla basiconica and three shorter, more slender sensilla (Fig. 36). Five pairs of stemmata present in an irregular lateral row; an anterior row of three contiguous stemmata followed by two more widely spaced stemmata posteriorly.

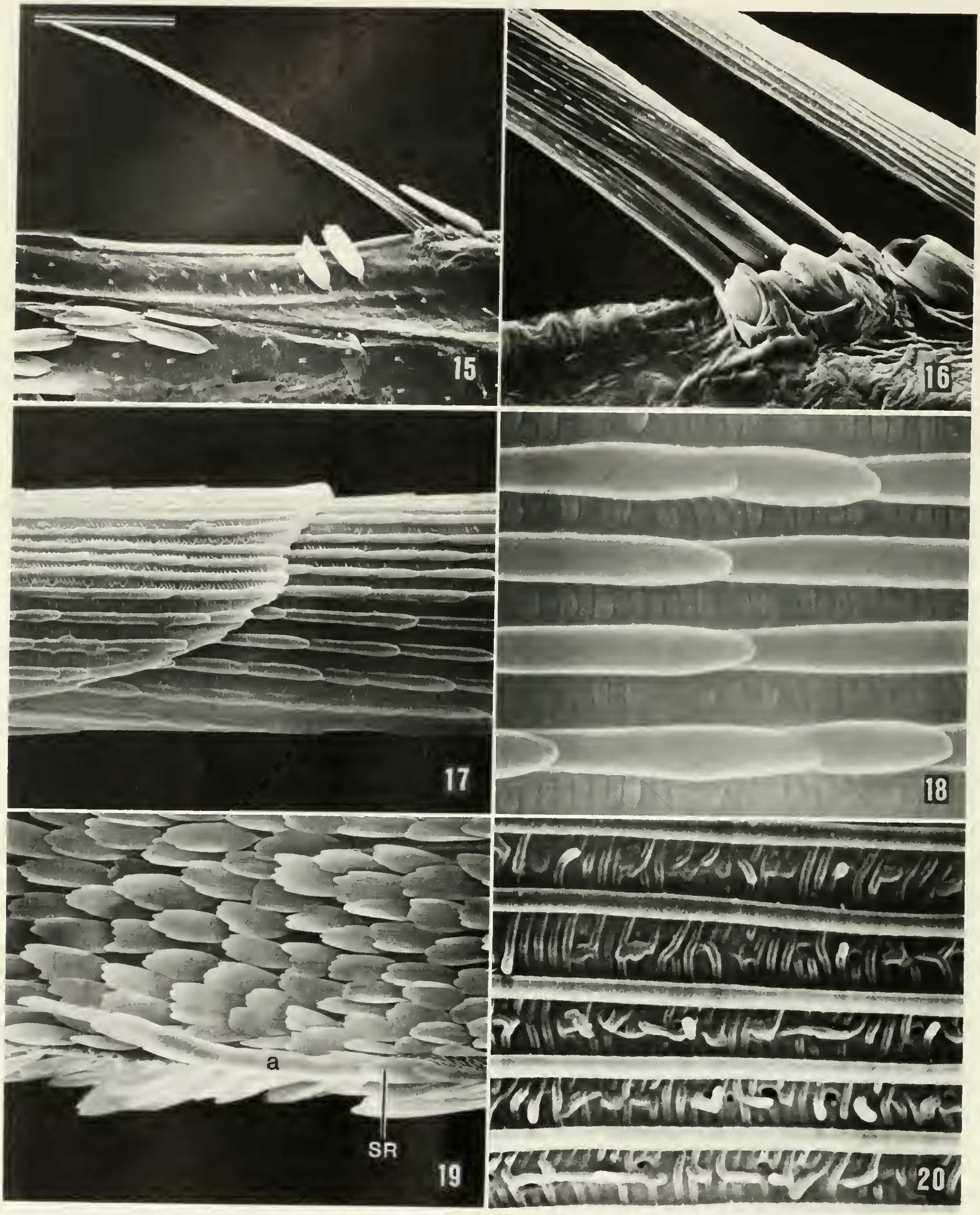
Body: Setae extremely reduced. Legs, prolegs, and crochets absent.

Tissue-feeding Instars

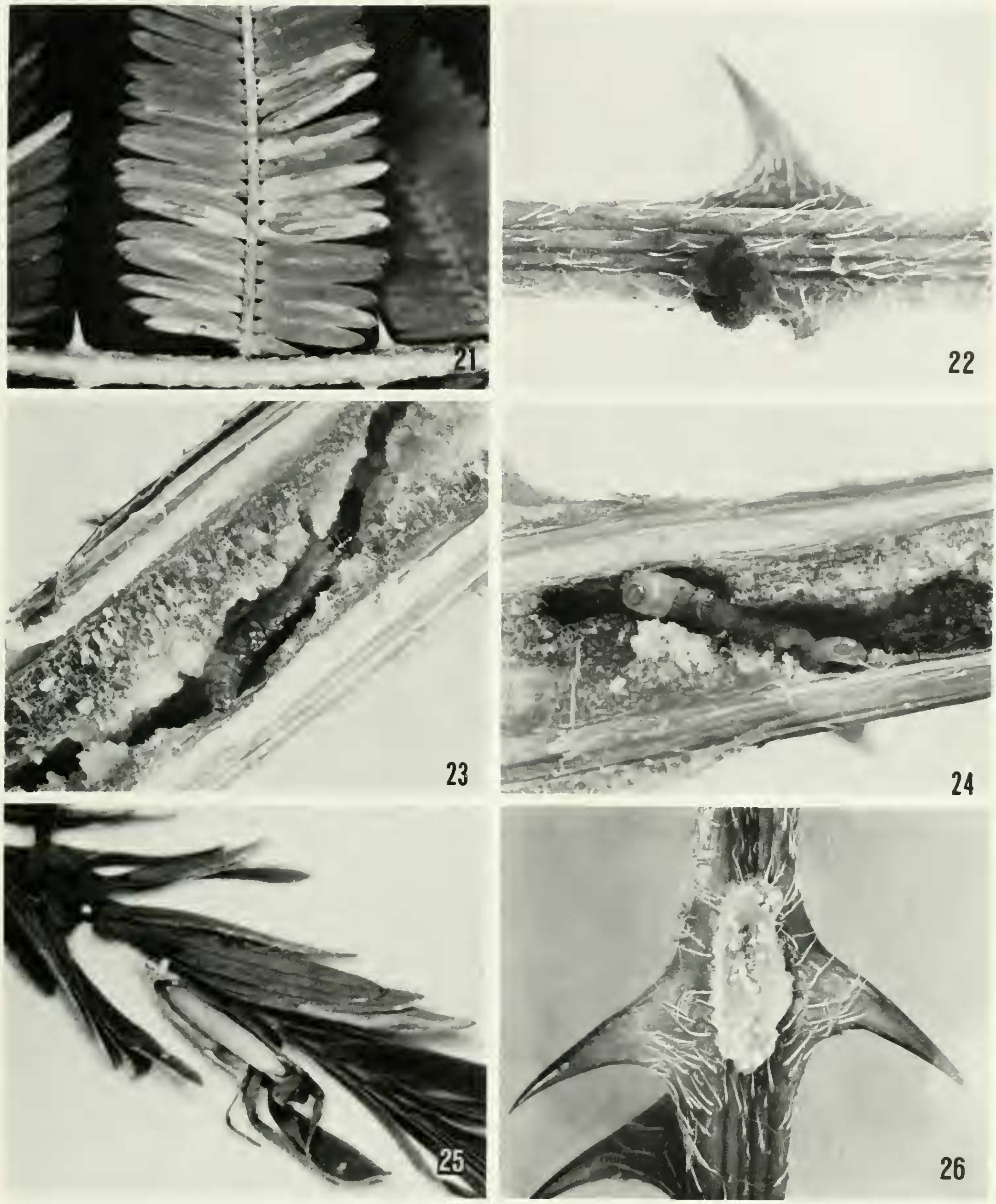
Head: Approximately round (Figs. 40, 51) with full complement of mouthparts, dark reddish brown. Frons (Fig. 64) moderately long, about 0.66 the distance to epicranial notch. Ecdysial line terminating at epicranial notch. Chaetotaxy relatively complete; all three MD setae present; AF2 absent; P2 reduced; L1 arising immediately caudad and



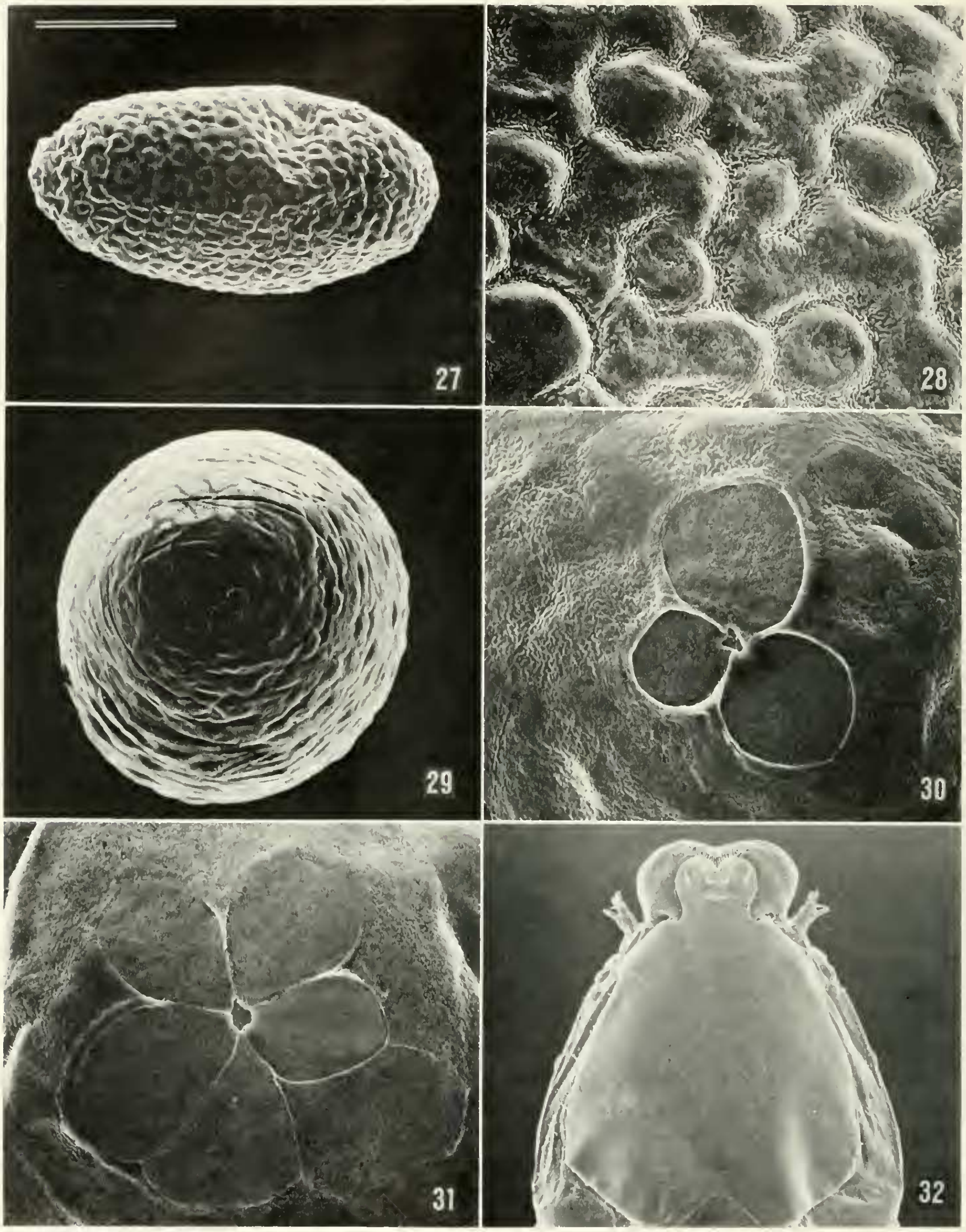
Figs. 9–14. *Neurostrota gunniella*, wing structure. 9, Hindwing, female, showing basal frenulum and more distal pseudofrenulum (270 μm). 10, Base of female frenulum (23.1 μm). 11, Surface detail of female frenulum (1.5 μm). 12, Base of male frenulum (10 μm). 13, Surface of male frenulum (3 μm). 14, Detail of Fig. 13 (1.5 μm). (Scale lengths in parentheses; bar scale for all photographs = Fig. 9.)



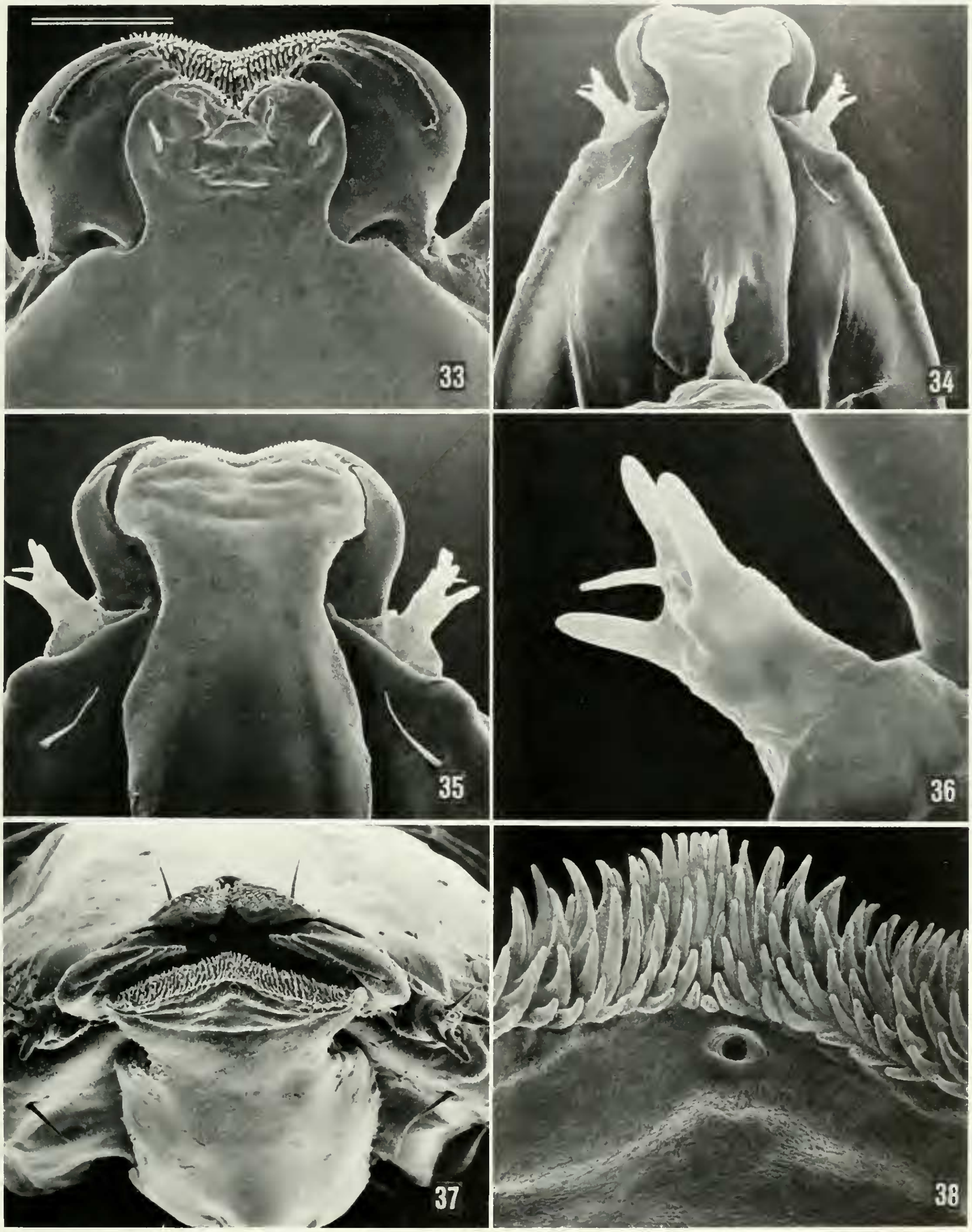
Figs. 15–20. *Neurostrota gunniella,* wing structure. 15, Male pseudofrenulum (120 μm). 16, Base of pseudofrenulum (17.6 μm). 17, Overlapping scales of pseudofrenulum (6 μm). 18, Surface detail of pseudofrenulum showing overlapping scutes (1.5 μm). 19, Subanal retinaculum (SR) of ventral forewing (100 μm). 20, Detail of scale (a) of Fig. 19 (2 μm). (Scale lengths in parentheses; bar scale for all photographs = Fig. 15.)



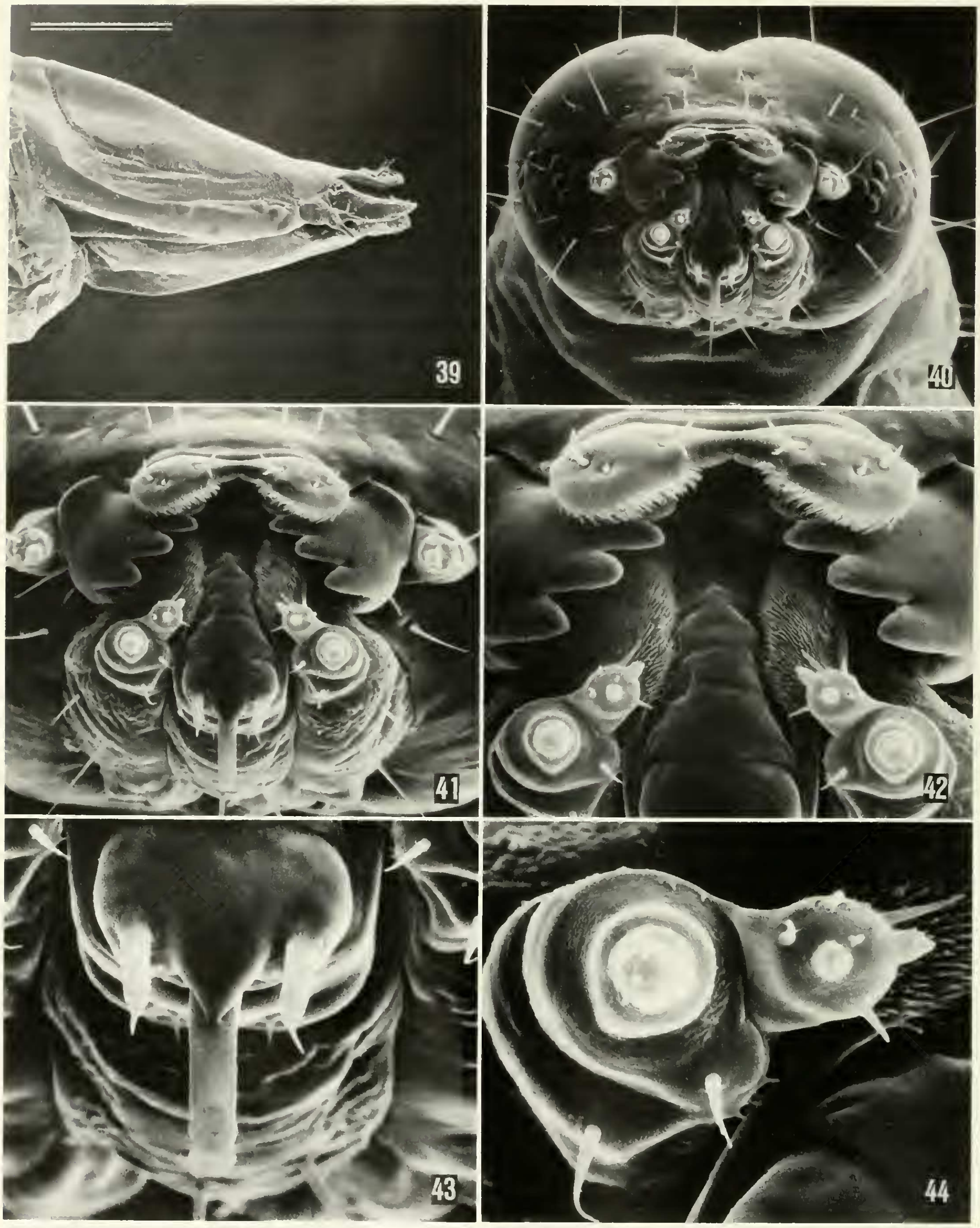
Figs. 21–26. *Neurostrota gunniella,* life history. 21, Leaf mines of sap-feeding larva on *Mimosa pigra.* 22, Frass ejected from stem burrow. 23, Larva inside tunnel within stem of *M. pigra.* 24, Moth larva killed by parasitic tachinid larva, *Elfia* n. sp. 25, Pupa inside cocoon spun on leaflets of *M. pigra.* 26, Cocoon spun on stem of *M. pigra,* Note frothy bubbles excreted by larva.



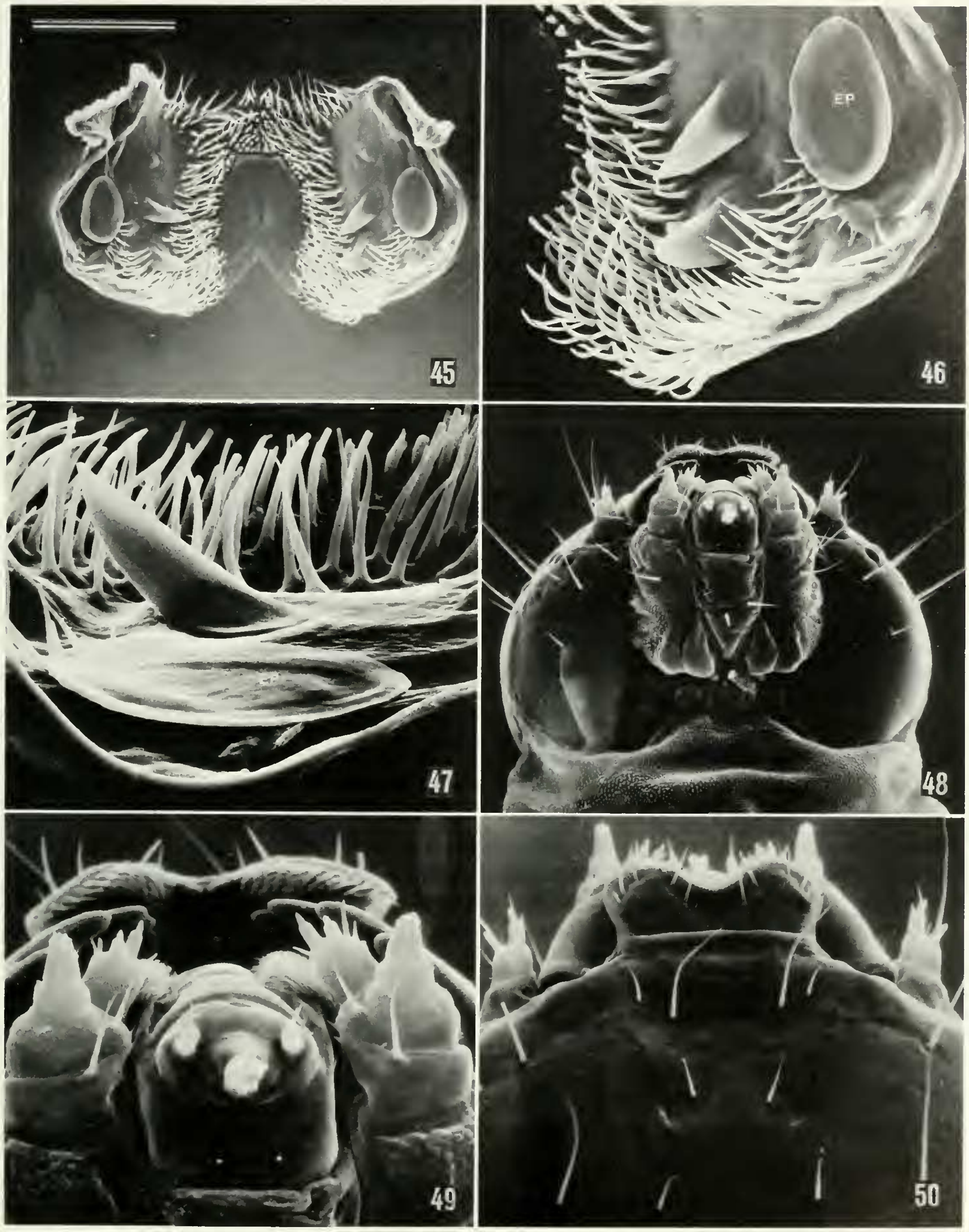
Figs. 27–32. *Neurostrota gunniella.* 27, Egg (120 μm). 28, Surface of egg chorion (23.1 μm). 29, Micropyle end (67 μm). 30, Detail of micropyle (15 μm). 31, Detail of micropyle (17.6 μm). 32, Sap-feeding larva, dorsal view of head (60 μm). (Scale lengths in parentheses; bar scale for all photographs = Fig. 27.)



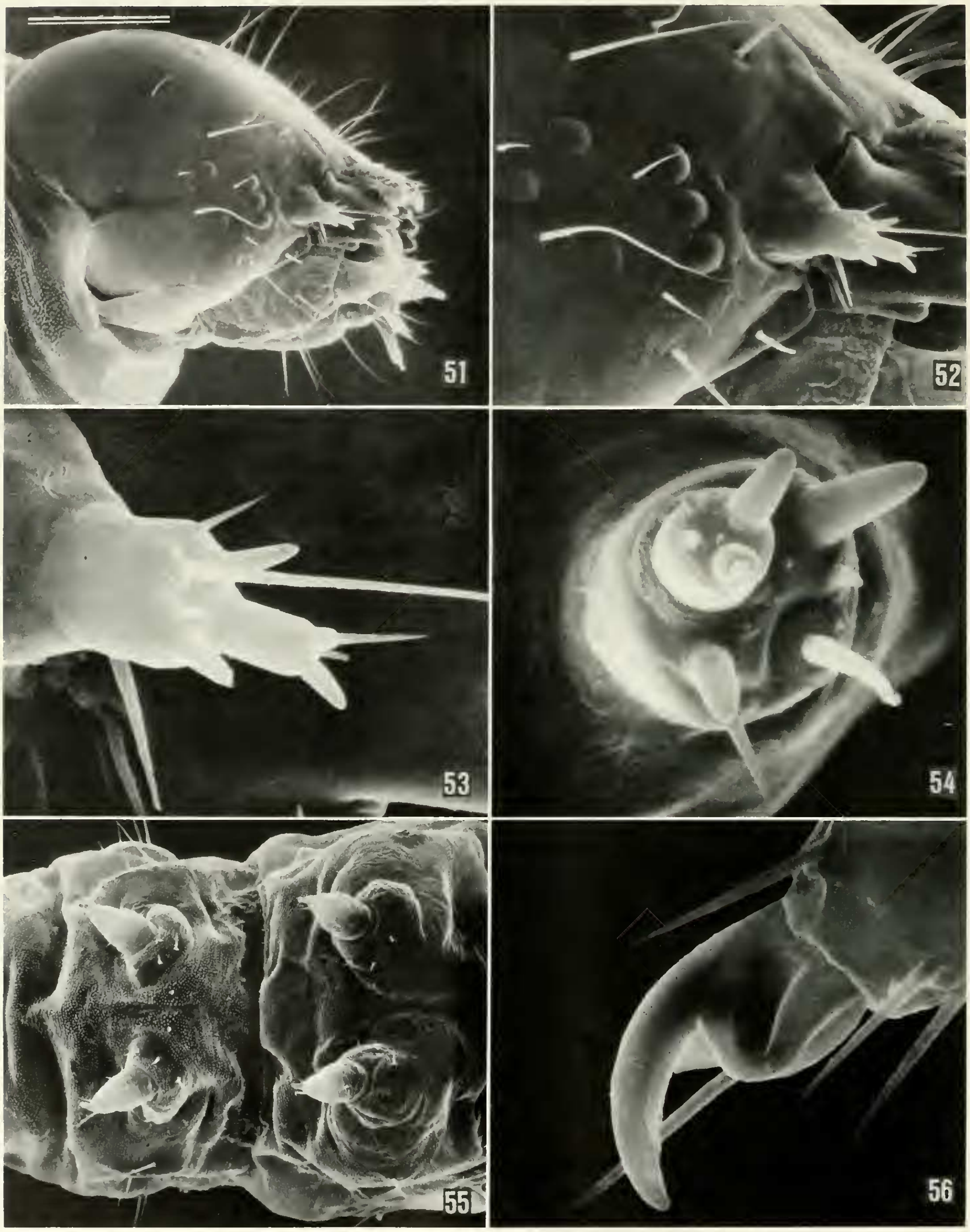
Figs. 33–38. *Neurostrota gunniella,* sap-feeding larva. 33, Labrum and mandibles, dorsal view (21.4 μm). 34, Ventral view of head (50 μm). 35, Labium and antennae, ventral view (30 μm). 36, Antenna, ventral view (7.5 μm). 37, Anterior view of mouthparts (27 μm). 38, Labium hypopharynx, ventral view; note aperture of vestigial spinneret (4.3 μm). (Scale lengths in parentheses; bar scale for all photographs = Fig. 33.)



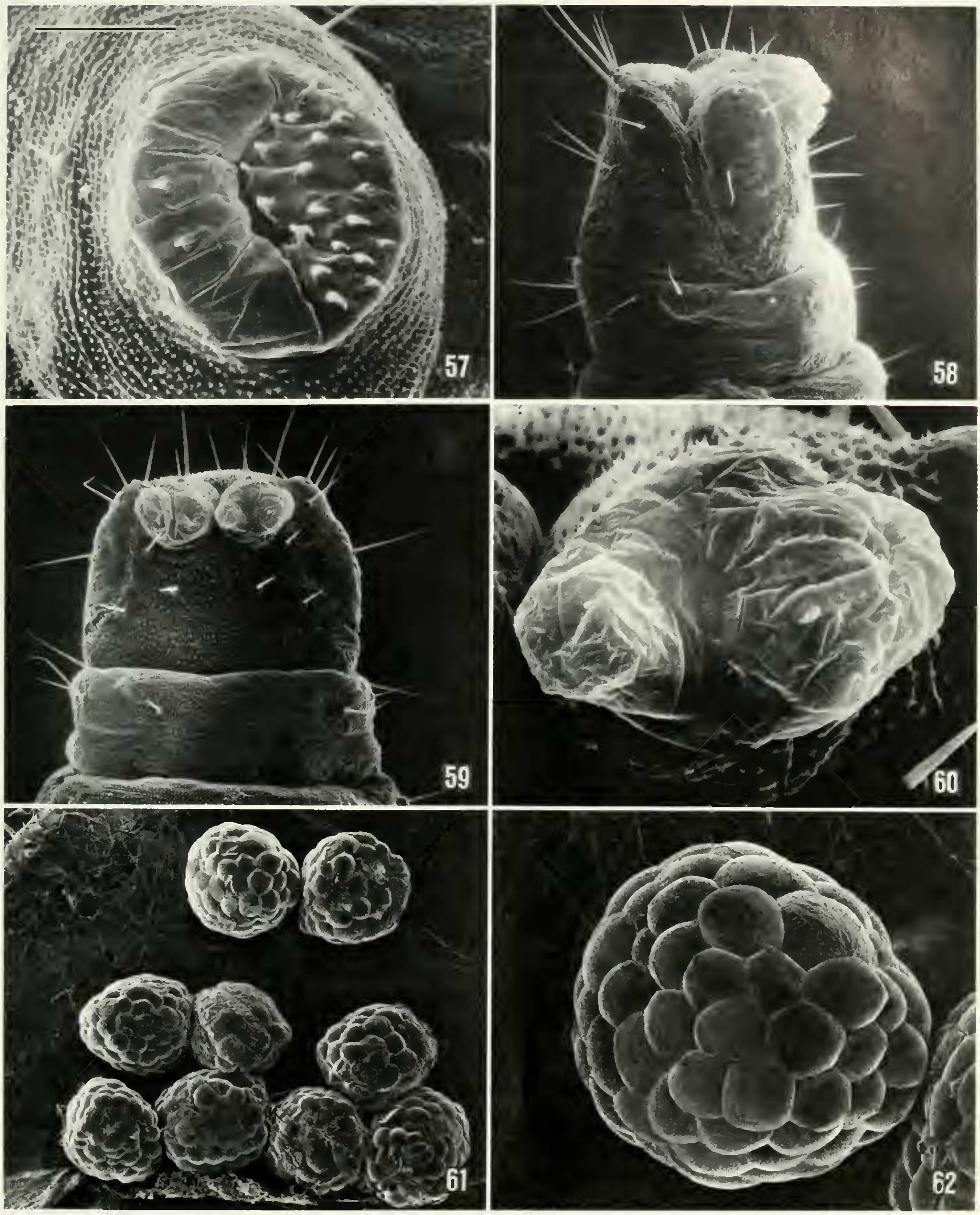
Figs. 39–44. *Neurostrota gunniella,* larva. 39, Sap-feeding larva, lateral view (60 μm). 40, Tissue-feeding (boring) larva, anterior view of head (176 μm). 41, Detail of Fig. 40 (100 μm). 42, Detail of mouthparts (60 μm). 43, Labial palpi and spinneret (38 μm). 44, Maxilla (25 μm). (Scale lengths in parentheses; bar scale for all photographs = Fig. 39.)



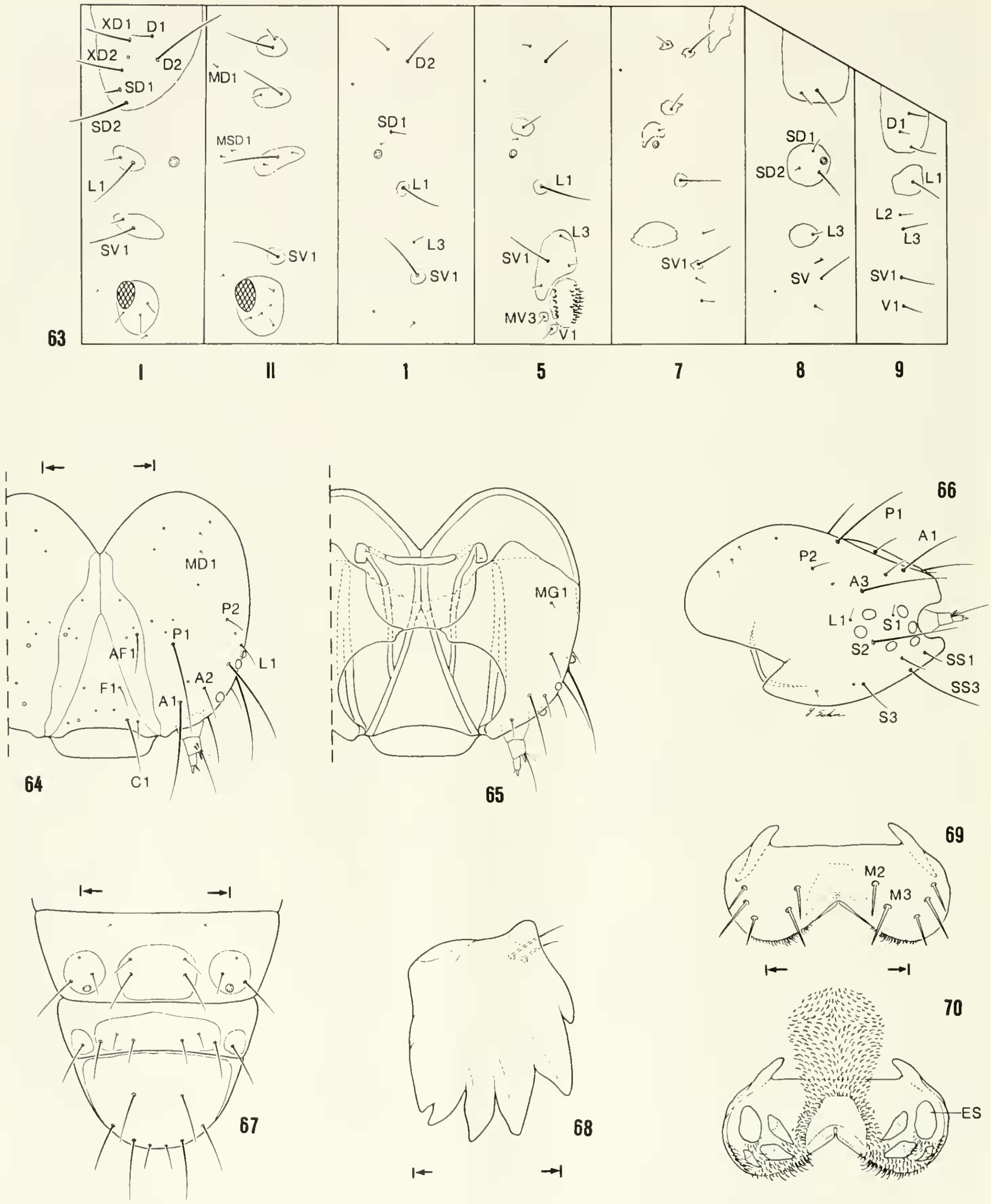
Figs. 45–50. *Neurostrota gunniella*, tissue-feeding larva. 45, Labrum, ventral view (43 μm). 46, Detail of Fig. 45; EP = epipharyngeal sclerite (17.6 μm). 47, Lateral view of ventral side of labrum (8.6 μm). 48, Head, ventral view (176 μm). 49, Detail of mouthparts, ventral view (60 μm). 50, Head, dorsal view (100 μm). (Scale lengths in parentheses; bar scale for all photographs = Fig. 45.)



Figs. 51–56. *Neurostrota gunniella,* tissue-feeding larva. 51, Lateral view of head (176 μm). 52, Detail of stemmatal region (75 μm). 53, Antenna (25 μm). 54, Distal view of antennal apex (13.6 μm). 55, Thorax, ventral view of T1 and 2 (231 μm). 56, Pretarsus, lateral view of T2 (15 μm). (Scale lengths in parentheses; bar scale for all photographs = Fig. 51.)



Figs. 57–62. *Neurostrota gunniella,* sap-feeding larva and cocoon. 57, Abdominal proleg, A4 (60 μm). 58, Lateral view of A9–10 (200 μm). 59, Ventral view of A9–10 (200 μm). 60, Anal proleg showing vestigial crochet (38 μm). 61, Surface of cocoon ornamented with frothy globules secreted by larva (38 μm). 62, Detail of globule (120 μm). (Scale lengths in parentheses; bar scale for all photographs = Fig. 57.)



Figs. 63–70. *Neurostrota gunniella,* morphology of tissue-feeding larva. 63, Chaetotaxy of pro- and mesothorax, abdominal segments 1, 5, 7–9. 64, Head dorsal view (0.2 mm). 65, Head, ventral view. 66, Head, lateral view. 67, Abdominal segments 8–10, dorsal (0.2 mm). 68, Mandible (0.1 mm). 69, Labrum, dorsal (0.1 mm). 70, Labrum ventral; ES = epipharyngeal sclerite. (Scale lengths in parentheses.)

between first and second stemmata. Six stemmata present, arranged in an oval (Figs. 52, 66). Antenna relatively short; sensilla as in Figs. 53–54. Labrum (Figs. 69, 70) with M1 absent; three pairs of epipharyngeal spines present, the lateral spine the most reduced; epipharyngeal sclerite (Figs. 45–47) thin, ovoid with entire margin, and raised slightly above epipharyngeal membrane. Mandible (Fig. 68) with three large medial cusps and three smaller, marginal cusps. Maxilla as in Figs. 42, 44. Spinneret (Figs. 43, 49) tubular, moderately elongate. Labial palpus with a relatively long, basal segment bearing one short sensillum and a minute apical segment bearing a larger sensillum.

Thorax: Pronotal plate variable, light to dark brown. L group bisetose on T1, trisetose on T2–3 with L2 and 3 minute. SV bisetose on T1, unisetose on T2–3. Legs (Fig. 55) well developed, with coxal plates well separated; pretarsal claw (Fig. 56) with large, triangular, axillary spine.

Abdomen: Dorsal and subdorsal plates of A8–10 dark brown. A1–2, 8–9 with eight pairs of primary setae; L2 absent. A3–5 with 10 pairs of primary setae; SV series trisetose. Crochets (Fig. 57) arranged in two scattered groups on A3–5, an anterior row of 2–3 spines and a posterior concentration of ca. 20 spines (Fig. 57); prolegs and crochets absent on A6. SV series bisetose on A7; L1 together with SD1–2 on spiracular plate; L series trisetose on A9; SD1 with D1–2 on dorsal plate. Anal plate (A10) with four pairs of setae (Figs. 58, 67); anal prolegs (Figs. 59, 60) nearly devoid of crochets, each proleg partially subdivided into two rounded tubercules with 1–2 small spines on each tubercule (Fig. 60).

Pupa (Figs. 71–82).—Length of largest pupa 5.3 mm; maximum width 1.0 mm. Vertex with a small, conical, multipointed apical process (cocoon cutter). Two pairs of small, nearly contiguous setae from lower frons near dorsal margin of labrum. Antenna long and straight, extending almost a fourth its length beyond abdomen. Wing sheath extending to caudal margin of A5. Hindleg slightly surpassing caudal apex of abdomen. Chaetotaxy as in Fig. 72; all setae extremely short. Dorsum of A2–6 with dense concentration of small, stout spines. Venter of A9 with a transverse row of four small stout spines; A10 with a pair of similar spines dorsally and two spines laterally (Figs. 80–82).

Cocoon (Figs. 25, 26, 61, 62).—Consisting of a firm white sheet of silk over some crevice in the stem or among the leaf pinnules, ornamented externally by 30–40 minute frothy balls approximately 0.3 mm in diameter.

Type.—Lectotype, ♀ (present designation, Davis) USNM.

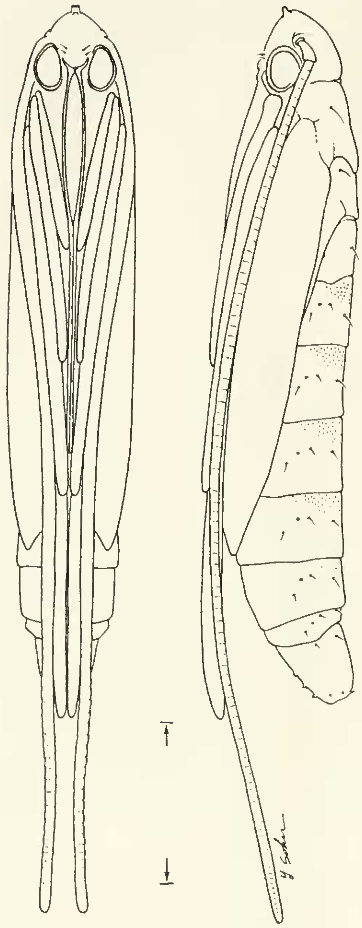
Type locality.—Brownsville, Texas.

Material examined.—COSTA RICA: *Guanacaste:* Tempisque: 1 ♂, 18 Jan, slides USNM 29938, 29939. CUBA: *Santiago de Cuba:* Santiago de Vegas [Cuba]: 2 ♂, 1 ♀, 22–23 Oct, ex *Mimosa asperata,* slide USNM 29936. MEXICO: *Guerrero:* Acapulco: 4 ♂, 3 ♀, em. 10–25 Nov, DRD 554.1, ex *Mimosa pigra*; 2 ♂, 5 ♀, em. 12 May–23 Jun, ex *Mimosa pigra*; 1 ♂, em. 6 Jun, ex *Mimosa* sp.; ca. 15 larvae, 8 Feb. ex *Mimosa pigra*; ca. 40 larvae, 28 Oct–1 Nov, ex *Mimosa pigra.* Barra Vieja, Acapulco: 1 ♀, em. 19 Jul, ex *Mimosa pigra.* Puerto Marquez, Acapulco: 6 ♂, 7 ♀, em. 21 Apr–30 Jun, ex *Mimosa pigra,* slides USMN 28687, 28804; 2 ♂, em. 25 Jun, ex *Neptunia plena. Tabasco:* Villahermosa: 1 ♀, 18 Mar, ex *Mimosa pigra. Veracruz:* Catemaco: 1 ♀, 16 Mar., ex *Mimosa pigra,* slide USNM 29933. Veracruz: 1 ♀, 14 Mar, ex *Mimosa pigra.* UNITED STATES: *Texas:* Cameron Co.: Brownsville: 1 ♀ (lectotype), Jun, slide USNM 29931; 11 ♀ (paralectotypes), Jun. San Benito: 6 ♀, 24–31 Jul; 2 ♀, Aug; 2 ♀, 8–15 Sep. Southmost: 1 ♂, 27 Oct. Fort Bend Co: Brazos Bend State Park: 1 ♀, 3 Aug. Harris Co: Houston: 1 ♂, 13 Jul, slide USNM 28440. All specimens in USNM.

Distribution.—Widespread in subtropi-

71

72



Figs. 71, 72. *Neurostrota gunniella*, pupa. 71, Ventral view (0.5 mm). 72, Lateral view. (Scale length in parenthesis).

cal or tropical, moderately wet to semi-arid habitats wherever the primary host, *Mimosa pigra* occurs; from southern Texas to Costa Rica and Cuba.

Hosts.—Leguminosae: *Mimosa pigra* L. and *Neptunia plena* Benth.; for secondary or potential hosts see Table 3.

Biology

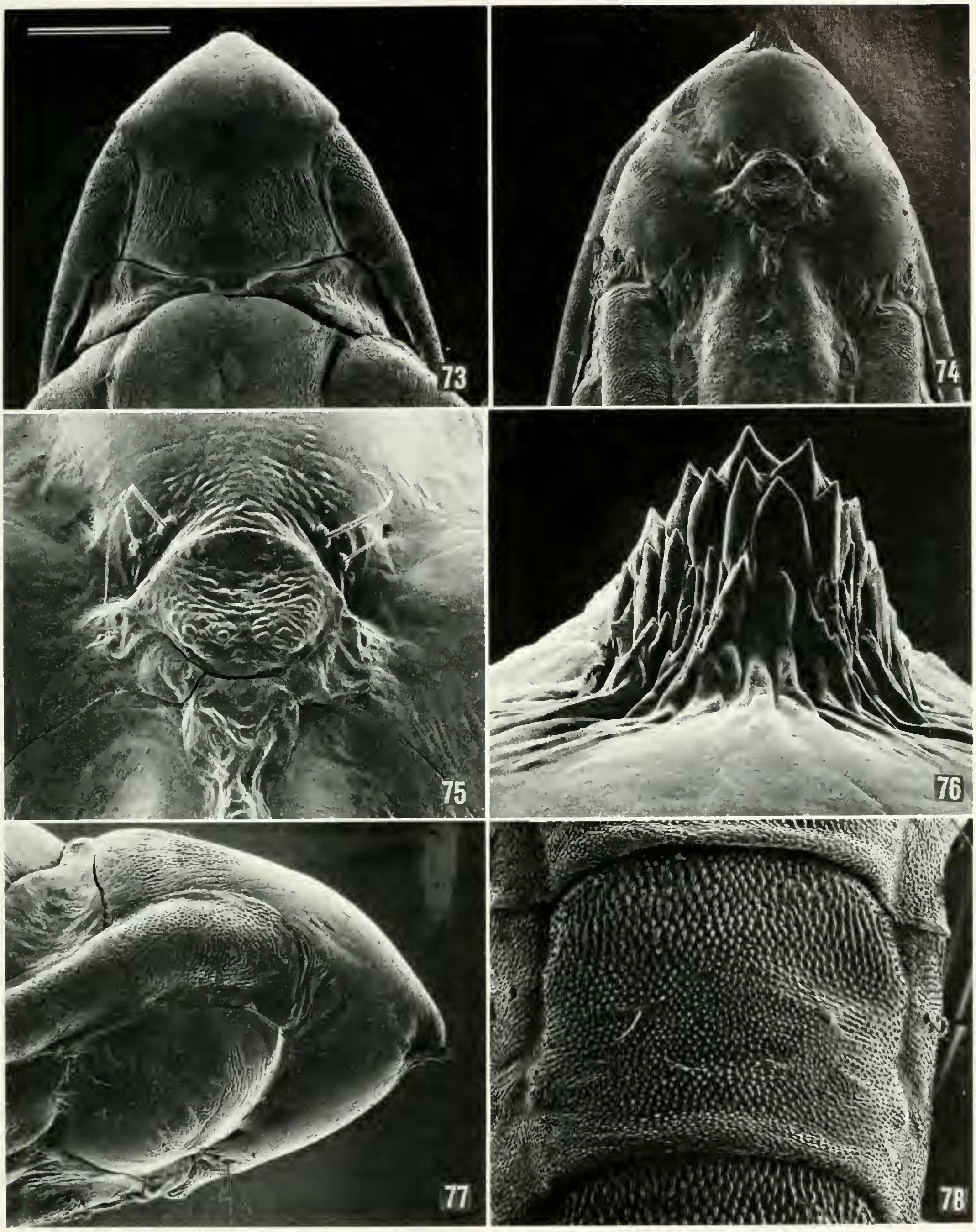
Rearing methods.—Stems of *M. pigra* infested with larvae of *N. gunniella* were collected at Barra Vieja and Pie de la Cuesta in the state of Guerrero, Mexico and shipped by air freight to Australia on 19th September 1986 and 5th December 1986, respectively. On arrival larvae were removed from these stems, transferred to potted plants of *M. pigra* and held in the quarantine facility at CSIRO, Long Pocket Laboratories, Brisbane. From this stock, a colony of *N. gunniella* was established on potted plants of *M. pigra* in a quarantine insectary air conditioned to 26 ± 1°C for 14 hours/day and 21 ± 1°C for the remainder of the day. Relative humidity was maintained above 55%. Overhead fluorescent lighting supplemented oblique natural lighting.

Newly emerged adults were fed a solution of ascorbic acid, (2 gms), honey (15 mls) and water (180 ml). Five pairs of fed adults were placed in a cage 45 × 45 × 90 cm high, with 4–8 potted plants of *M. pigra*. After the eggs laid on the plants had hatched, the larvae were provided with fresh plants of *M. pigra* as required, until development was completed.

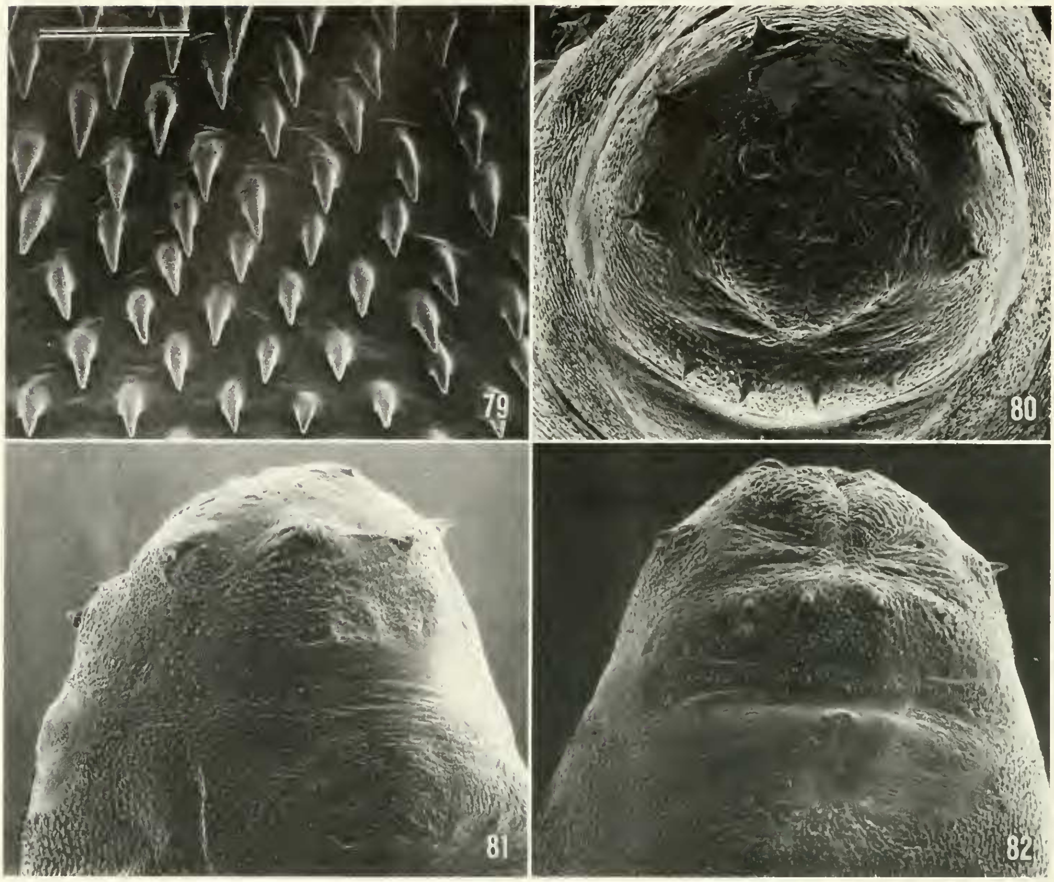
Biological studies.—Studies were carried out in "Conviron" constant temperature cabinets at 25 ± 0.5°C with a 14:10 photoperiod. The number of eggs/female/day (fecundity) was measured and preferred oviposition sites determined by counting the number of eggs laid on different parts of the plant. Egg incubation time and the size of eggs were measured. The number and duration of each larval instar was recorded by examining larvae every day and measuring the width of their head capsules. Duration of pupal stage and adult longevity were also measured.

Eggs were usually deposited singly on the ventral side of mature leaves growing at either the first or second node from the tip. The most favoured site being on the secondary rachis adjacent to a leaf hair.

Eggs hatched after 4–5 days. First and second instar larvae mined pinnules (Fig. 21), with as many as 5 being mined by each larva. Third instar larvae usually entered the primary rachis where a pinna was attached and tunnelled towards the stem where they fed either in the petiole bulb or in the



Figs. 73–78. *Neurostrota gunniella,* pupa. 73, Head, dorsal view (231 μm). 74, Head, ventral view (231 μm). 75, Detail of frons (86 μm). 76, Detail of frontal process (cocoon cutter) (30 μm). 77, Head, lateral view (176 μm). 78, Dorsal view of A2 (176 μm). (Scale lengths in parentheses; bar scale for all photographs = Fig. 73.)



Figs. 79–82. *Neurostrota gunniella*, pupa. 79, Dorsal spines of A3 (27 μm). 80, Caudal view of A10 (86 μm). 81, Lateral view of A9–10 (100 μm). 82, Ventral view of A9–10 (86 μm). (Scale lengths in parentheses; bar scale for all photographs = Fig. 79.)

stem (Fig. 23). Sometimes they exited and re-entered the stem at another node or near a prickle. Frass was often visible where the larvae entered the stem (Fig. 22). There were eight larval instars. The final instar consisted of three distinct phases based on behavioral and/or color changes. The first phase was the typical, tissue-feeding form; in the second phase the larva usually exited from the stem, spun a cocoon, and changed from a dark, blue-green color back to the cream color of the earliest instars. In the final phase, herein referred to as the prepupa (Fig. 83, Table 1), the larva was inactive for ca. 24 hours and then pupated. If disturbed, the prepupa moved in a spiralling motion similar to that of the pupa.

Most mature larvae exited from the stem and pupated in a slender cocoon usually spun between pinnules (Fig. 25), or in crevices on or within the stem (Fig. 26). The outside of the cocoon was ornamented with small, pearly-white, frothy balls (Figs. 26, 61, 62) discharged from the anus of mature larvae and attached by projecting their posterior through slits in the cocoon. These slits were then covered with additional silk and the larvae entered the prepupal stage. Adults emerged 7 days after pupation. The duration of life-cycle stages of *N. gunniella* and

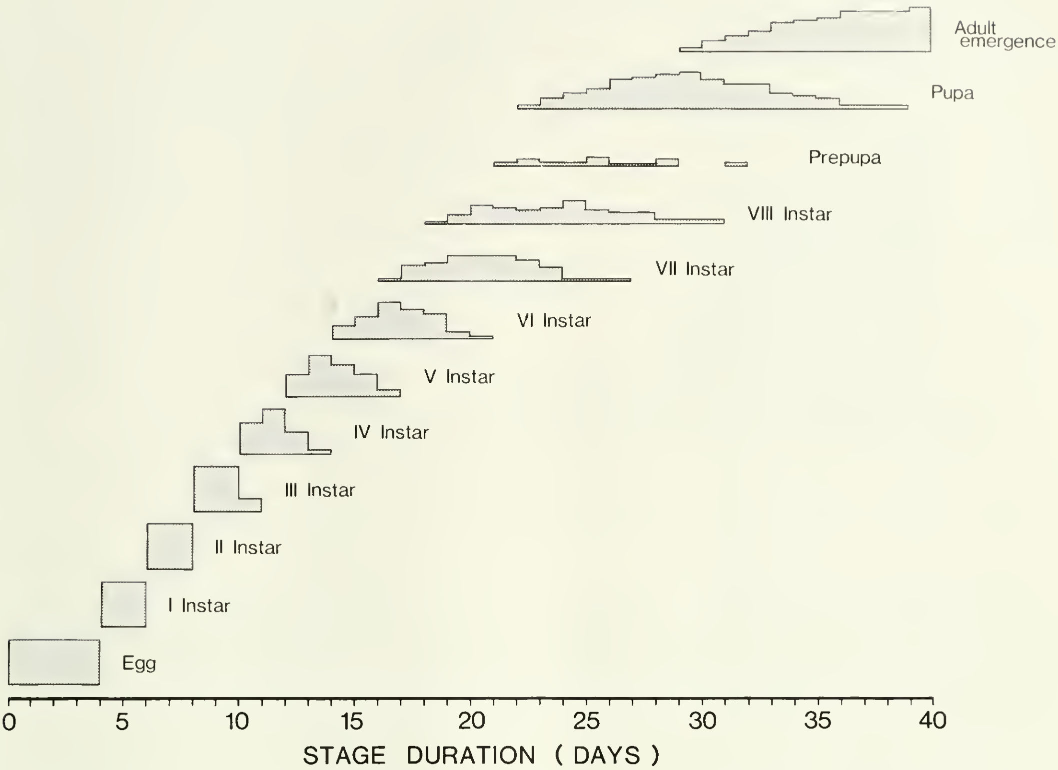


Fig. 83. Duration of life-cycle stages of *Neurostrota gunniella* and the proportional distribution of the stages for each day. The histograms show the proportion of each stage and adult emergence present on each day.

the proportional distribution of stages for each day of development is shown in Fig. 83.

Adults when resting had their antennae lying back along the body and extending beyond the wings; the body was usually held so that the head was slightly depressed; the fore- and mid-legs were held together to the end of the tibia but then separated at an angle of *ca.* 45°, and the hind legs were held back along the body before being slightly splayed. In addition to the typical frenular differences, males could be distinguished from females by differences in the appearance of scales arising from the terminal segments of the abdomen. In females the scales formed a cylinder that enveloped the ovipositor whereas in males the scales overlaid the valvae. The ratio of reared males to females was 1:1. Adults fed on liquid nutrient solution. The age-specific fecundity and survival of adult females is shown in Fig. 84. The duration, number and development time of the stages of *N. gunniella* at 25 ± 0.5°C is summarized in Table 1 and Fig. 83.

Host specificity tests.—In Mexico, stems of leguminous plants growing adjacent to *M. pigra* were dissected and examined for *N. gunniella.* These plants included seven *Mimosa* spp., two *Acacia* spp., *Schrankia distachya* DC., *Prosopis juliflora* (Swartz) DC., *Parkinsonia aculeata* L., *Leucaena leucocephala* (Lam.) de Wit, and *Neptunia plena. N. gunniella* was not encountered in any of these plants except *N. plena.* One potted plant of *Mimosa* sp. (not *M. pigra*), growing in the laboratory grounds was found infested with larvae of *N. gunniella.* Larvae in *N. plena* and *Mimosa* sp. completed development.

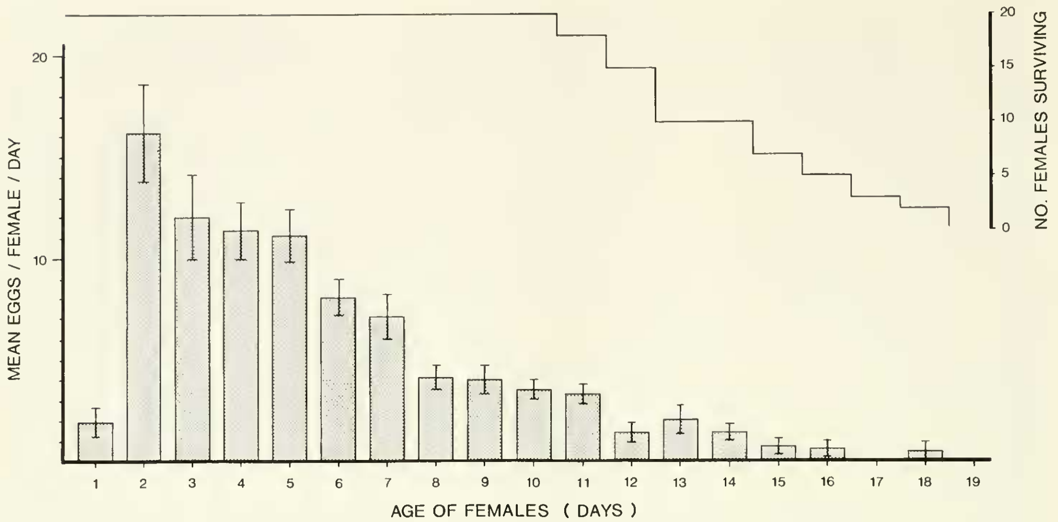


Fig. 84. Age-specific fecundity and survival of *Neurostrota gunniella* females (n = 20).

In Australia, host specificity was determined by observing the oviposition of adult females and feeding by first instar larvae. These behavioral characteristics of *N. gunniella* were studied using 100 species of plants representing 18 plant families and included 69 species of Leguminosae (Table 2). These are the same species used in studies with other insects already released for the biological control of *M. pigra* in Australia (Kassulke et al. 1990) with the addition of four Australian species of *Neptunia* and one of *Adenanthera, Archidendron* and *Pararchidendron.* Species of *Neptunia* were added because *N. gunniella* had been reared occasionally from *N. plena* in Mexico (records of CSIRO exploratory unit, Mexico). The other three genera were added to increase the range of woody Australian native legumes tested.

Table 1. Duration of development (days) of *Neurostrota gunniella* on *Mimosa pigra* at 25 ± 0.5°C (n = 20).

Stage	$\bar{x}$	Range
Egg (incubation)	4.0	4–5
Larvae		
1st instar	2.0	—
2nd instar	2.0	—
3rd instar	2.3	2–3
4th instar	2.3	2–3
5th instar	2.8	2–4
6th instar	3.1	2–4
7th instar	3.4	2–4
8th instar	3.3	2–7
Prepupa	1.0	—
Pupa	7.0	—
Adult longevity	15.6	11–19
Total life cycle	33.2	28–40
Number of eggs/female	85.6	49–128

Larval feeding.—Excised pinnae of *M. pigra* each with at least ten eggs due to hatch the next day, were placed on the first mature leaf of each test plant and on a plant of *M. pigra.* Those species on which larvae fed were held until larvae either died or completed development. This procedure was repeated until all plant species had been tested at least 3 times. In these tests, neonate larvae fed and completed development on 6 species: *M. pigra, M. pudica, Neptunia dimorphantha* Domin, *N. gracilis* Benth., *N. major* (Benth.) Windler and *N. monosperma* F. Muell. In one trial with *Acacia podalyriifolia* A. Cunn. ex. G. Don and another with *Glycine max* (L.) Merr., one larva survived and developed to the 3rd instar before dying. On another 37 plant species, larvae fed briefly in some trials before dying while still in the first instar (Table 3).

Table 2. Plants tested to determine host specificity of *Neurostrota gunniella.*

Family	Genus/Species	Common Name
1. Taxonomically unrelated plants		
Anacardiaceae	*Mangifera indica*	mango
Annonaceae	*Annona reticulata*	custard apple
Bignoniaceae	*Jacaranda mimosifolia*	jacaranda
Caricaceae	*Carica papaya*	pawpaw
Compositae	*Helianthus annuus*	sunflower
	Lactuca sativa	lettuce
Cruciferae	*Brassica oleracea* var. *botrytis*	cauliflower
Lauraceae	*Persea americana*	avocado
Malvaceae	*Gossypium hirsutum*	cotton
Myrtaceae	*Eucalyptus maculata*	spotted gum
	E. miniata	
	E. tereticornis	forest red gum
	E. tetrodonta	Darwin stringy bark
	Leptospermum longifolium	tea tree
	Psidium guajava	guava
	Syzygium luehmannii	small leaf water-gum
Poaceae	*Saccharum officinarum*	sugar cane
	Sorghum vulgare	sorghum
	Zea mays	maize
Proteaceae	*Macadamia ternifolia*	Queensland nut
Rosaceae	*Fragaria × ananassa*	strawberry
	Malus sylvestris	apple
	Prunus persica	peach
	Rosa sp.	rose
Rubiaceae	*Coffea arabica*	coffee
Rutaceae	*Citrus limon*	lemon
	C. reticulata	mandarin
	C. sinensis	orange
Simmondsiaceae	*Simmondsia chinensis*	jojoba
Solanaceae	*Lycopersicon esculentum*	tomato
Theaceae	*Camellia sinensis*	tea
2. Taxonomically Related Plants		
Leguminosae	*Acacia aulacocarpa*	hickory wattle
	A. auriculiformis	
	A. cincinnata	
	A. crassicarpa	
	A. deanii	
	A. × decurrens	ferny wattle
	A. difficilis	
	A. dimidiata	
	A. holosericea	war-roon
	A. latescens	
	A. leptocarpa	
	A. mangium	
	A. oncinocarpa	
	A. podalyriifolia	silver wattle
	A. spectabilis	Pilliga wattle
	Adenanthera pavonina	red sandalwood
	Albizia lebbeck	woman's tongue
	Arachis hypogaea	peanut
	Archidendron hendersonii	

Table 2. Continued.

Family	Genus/Species	Common Name
	Bauhinia galpini	
	B. variegata	
	Caesalpinia ferrea	
	Cajanus cajan	orchid tree
	Calopogonium mucunoides	leopard tree
	Cassia alata	pigeon pea
	C. artemisioides	calopo
	C. fistula	ringworm cassia
	C. mimosoides	cassia
	Cathormion umbellatum	golden shower
	Centrosema pubescens	
	Delonix regia	
	Desmanthus virgatus	centro
	Desmodium tortuosum	poinciana
	Dichrostachys cinerea	
	D. spicata	desmodium
	Enterolobium contortisiliquum	
	Erythrophleum chlorostachys	Cooktown ironwood
	Glycine max	soybean
	Lablab purpureus	lablab bean
	Leucaena diversifolia	
	L. lanceolata	
	L. leucocephala	leucaena
	L. macrophylla	
	L. pallida	
	L. shannonii	
	Lysiphyllum hookeri	white bauhinia
	Macroptilium atropurpureum	siratro
	Medicago sativa	lucerne
	Mimosa invisa	giant sensitive plant
	M. pigra	mimosa, giant sensitive plant
	M. pudica	common sensitive plant
	Neptunia dimorphantha	
	N. gracilis	native sensitive plant
	N. major	
	N. monosperma	
	Pararchidendron pruinosum	
	Peltophorum pterocarpum	
	Piliostigma malabaricum	
	Pisum sativum	pea
	Pongamia pinnata	pongamia
	Pueraria phaseoloides	puero
	Samanea saman	raintree
	Sesbania formosa	
	Stylosanthes hamata cv. *Verano*	stylo
	Tamarindus indica	tamarind
	Vicia faba	broadbean
	Vigna mungo	mung bean
	V. radiata	mung bean
	V. unguiculata	cowpea

Table 3. Larval feeding, oviposition, and development of *Neurostrota gunniella*.

	Larval Trials			Adult Trials		
	No. Trials	No. with Feeding	Stage Reached	No. Trials	No. with Eggs	Stage Reached
Acacia crassicarpa	3	3	1st Instar	3	0	—
A. leptocarpa	4	3	1st Instar	4	0	—
A. mangium	4	4	1st Instar	5	1	1st Instar
A. oncinocarpa	3	1	1st Instar	3	0	—
A. podalyriifolia	3	2	1st Instar*	10	1	1st Instar
Adenanthera pavonina	3	2	1st Instar	3	0	—
Albizia lebbeck	3	1	1st Instar	4	0	—
Arachis hypogaea	3	3	1st Instar	4	0	—
Brassica oleracea	3	2	1st Instar	3	0	—
Cajanus cajan	3	1	1st Instar	3	0	—
Cassia alata	3	2	1st Instar	4	0	—
C. artemisioides	3	1	1st Instar	4	0	—
C. fistula	3	1	1st Instar	3	0	—
C. mimosoides	3	1	1st Instar	4	0	—
Delonix regia	3	2	1st Instar	3	0	—
Desmanthus virgatus	3	1	1st Instar	4	1	1st Instar
Desmodium tortuosum	3	2	1st Instar	3	0	—
Glycine max	3	3	1st Instar*	4	0	—
Gossypium hirsutum	3	2	1st Instar	3	0	—
Helianthus annuus	3	1	1st Instar	3	0	—
Lablab purpureus	4	1	1st Instar	4	0	—
Lactuca sativa	3	1	1st Instar	3	0	—
Leucaena diversifolia	3	1	1st Instar	3	0	—
L. lanceolata	3	1	1st Instar	3	0	—
L. leucocephala	3	1	1st Instar	4	0	—
L. macrophylla	3	1	1st Instar	3	0	—
L. shannonii	4	4	1st Instar	6	1	1st Instar
Lycopersicon esculentum	3	1	1st Instar	4	0	—
Macroptilium atropurpureum	3	2	1st Instar	4	0	—
Malus sylvestris	4	3	1st Instar	3	0	—
Medicago sativa	3	1	1st Instar	4	0	—
Mimosa pigra	5	5	Adult	5	5	Adult
M. pudica	3	1	Adult	4	4	Adult
Neptunia dimorphantha	3	2	Adult	3	3	Adult
N. gracilis	3	1	Adult	4	3	Adult
N. major	3	3	Adult	3	3	Adult
N. monosperma	3	2	Adult	5	3	Adult
Piliostigma malabaricum	3	2	1st Instar	3	0	—
Pongamia pinnata	3	1	1st Instar	3	0	—
Prunus persica	3	1	1st Instar	3	0	—
Samanea saman	3	1	1st Instar	4	0	—
Sorghum vulgare	3	1	1st Instar	3	0	—
Tamarindus indica	3	1	1st Instar	4	0	—
Vigna mungo	3	2	1st Instar	4	0	—
V. unguiculata	3	3	1st Instar	4	0	—

* 1 larva reached 3rd Instar.

Table 4. Development of *Neurostrota gunniella* on five test plants and number of adults emerged in F1 generation from five gravid females in no choice tests.

Plant Species	Development (Days) Egg to Adult		% Larval Mortality	Adults Emerged F_1 Generation	
	$\bar{x}$	Range		$\bar{x}$	Range
Mimosa pigra	36	31–48	<25	95	52–132
M. pudica	42	37–46	>70	18	1–51
Neptunia dimorphantha	35	31–48	>85	22	5–38
N. gracilis	40	33–37	>90	3	0–6
N. major	48	34–63	>96	5	2–7
N. monosperma	35	31–47	>70	10	0–39

Oviposition.—Plant species which were fed on by larvae in feeding tests were further tested for selection by females for oviposition in the absence of *M. pigra.* These no choice tests were repeated at least three times. Five pairs of newly emerged adults were fed nutrient solution and placed in a cage with a potted test plant for five days. A fine mist of water was sprayed into the cage each morning and afternoon for adults to drink. Plants were examined for the presence of eggs and those with eggs were examined daily for larval feeding. Observations continued until larvae either died or completed development. Species of *Acacia* which have bipinnate leaves in the juvenile stage were tested with and without pinnules. To avoid any possible disruption of behavior no *M. pigra* was present in the laboratory when these tests were carried out.

Eggs were laid and larvae completed development on the same 6 plant species as in the larval feeding tests, i.e. *M. pigra, M. pudica, N. dimorphantha, N. gracilis, N. major* and *N. monosperma.* Eggs were also laid on *Acacia mangium* Willd. in one of five trials, on *A. podalyriifolia* in one of ten trials, on *Desmanthus virgatus* (L.) Willd. in one of four trials and on *Leucaena shannonii* Donn. Smith in one of six trials, but in all cases larvae died in the first instar after mining in a few pinnules (Table 3).

Fecundity and development.—Oviposition averaged 86 eggs per female on *M. pigra* (n = 20). Oviposition could commence the first night after emergence but most eggs were laid during the second night. Eggs were difficult to see and accurate egg counts were not made on *M. pudica, N. dimorphantha, N. gracilis, N. major* and *N. monosperma.* The number of larval mines that developed following egg-laying by five gravid females on each of these species varied from an average of 128 on *M. pigra,* to 26 on *M. pudica,* 37 on *Neptunia dimorphantha,* 25 on *N. gracilis,* 60 on *N. major* and 7 on *N. monosperma* (n = 3). On these species, there was little difference in the duration of larval development (Table 4). Adults obtained from larvae that developed on these plants were returned to plants of the same species to determine if successive generations could develop. Successive generations were able to develop on these six species but larval mortality was greater than 96% on *N. major,* 90% on *N. gracilis,* 85% on *N. dimorphantha,* and 70% on *M. pudica* and *N. monosperma.* Mortality on *M. pigra* was less than 25% (Table 4). Larvae caused no significant damage to the *Neptunia* spp. whereas they always caused heavy damage to *M. pigra* and occasionally moderate damage to *M. pudica.*

Observations in Mexico and Central America

In Mexico and Central America, *M. pigra* has two varieties, *M. pigra* var. *pigra* L. and *M. pigra* var. *berlandieri* (Gray. ex Torr.) B. L. Turner (Turner, 1959). Both varieties are attacked by *N. gunniella,* and in Mexico and Costa Rica all stands of *M. pigra* examined

Table 5. Parasitoids associated with *Neurostrota gunniella* in Mexico.

Diptera	
Chloropidae	
	Fiebrigella sp.
	Fiebrigella new sp. nr. *catalpae* (Malloch)
Tachinidae	
	Elfia new sp. undescribed
Hymenoptera	
Perilampidae	
	Perilampus sp.
Braconidae	
	Apanteles sp.
	Bracon sp.
	Hypomicrogastar sp.
	Orgilus sp., probably new sp.
	Phanomeris sp.
Chalcididae	
	Brachymeria sp.
Eulophidae	
	Elasmus sp.
	Horismenus sp.

were infested with the moth. Typically a 20 cm piece of stem would be infested by 5 larvae.

Parasitization of *N. gunniella*

In Mexico, field collected stems of *M. pigra* infested with larvae of *N. gunniella* were caged in the laboratory for emergence of parasitoids (Table 5). Many more parasitoids than adult moths emerged, with *Elfia* n. sp. (Tachinidae) being by far the most numerous. Figure 24 shows *N. gunniella* being attacked by a larva of *Elfia* n. sp. The chloropid, *Fiebrigella* sp., emerged only infrequently and may not represent a parasitic relationship. Sabrosky (1950) suggested that the rather random appearance of this species in such rearings may indicate they are scavengers.

Discussion

Morphology and systematics.—The stem-boring habit of the larva was first reported by Busck (1934), based upon rearings in Cuba by H. R. Otero. Busck also described a second species of *Neurostrota* (*pithecolobiella*) from Cuba, a stem borer in the leguminous tree *Pithecellobium saman* (Jacq.) Benth. However, on the basis of the male genitalia, *pithecolobiella* does not appear congeneric with the type of the genus, *N. gunniella*. A second, undescribed species of *Neurostrota* has been collected at light near Tamazunchale, Mexico by the senior author (Davis). Another species, similar to the latter, is also known to bore in stems of *Inga vera* Willd., (Leguminosae) in Puerto Rico, thus bringing the number of known species of *Neurostrota* to three. Although no further published reports have been found on stem-boring Gracillariidae, other than the above references by Busck and the gall-making or shoot-mining habits of a few other Gracillariidae, it appears from collecting records that a true stem-boring habit has arisen perhaps several times within tropical/subtropical Gracillariidae.

One unusual morphological feature present in the adults of *N. gunniella*, is the development of a supplementary wing coupling mechanism in both sexes. In addition to the frenular bristles (single in the male and double in the female), these moths possess a prominent pseudofrenulum arising from the costal margin of the hindwing near the termination of Sc. The pseudofrenulum couples with a row of stiff, specialized scales located along the ventral hind margin in the anal area of the forewing. Because of its location, it is proposed that this accessory retinaculum be termed the subanal retinaculum, in comparison to the subcostal and subdorsal retinaculum described by Tillyard (1918) and Braun (1924). The longitudinal scale ridges of the subanal scales in *Neurostrota* are strengthened by the fusion of all scutes (Fig. 20), similar to the subdorsal retinacular scales described for Opostegidae (Davis, 1989).

In *N. gunniella*, the pseudofrenulum is composed of three to four, tightly appressed, piliform scales (Figs. 15, 16), usually accompanied by four or five much shorter, broader costal scales which overlap more basally. Although often appearing to be fused (as in the case of the male frenulum), the piliform scales are separated throughout their length and closely overlap each other (Fig. 17). In contrast to the more specialized, cylindrical bristles of the male and female frenulum, the longitudinal ridges of the pseudofrenulum are not entire but instead are subdivided into overlapping scutes (Fig. 18).

Busck (1934) and others have noted the presence of similar pseudofrenula in a few other gracillariid genera (*Micrurapteryx, Neurobathra,* and *Parectopa*), and Kumata (in litt.) has observed their presence in *Canopomorpha, Cuphodes, Epicephala, Liocrobyla, Stomphastis,* and a few *Acrocercops.* A similar pseudofrenulum has been illustrated in Heliozelidae (Common 1970, Fig. 36.15B). Less specialized, pseudofrenular scales have also been noted in several genera of Cosmopterigidae (Hodges 1978, Figs. 1–3). Within this family and according to genus, a graduated series varying from a relatively long row of costal scales to a more concentrated group of a few piliform scales can be present.

The ventral surface of the labrum in the tissue-feeding instars of *N. gunniella* bears the typical lepidopterous complement of three pairs of spinose, epipharyngeal setae. Also present is a pair of flat, oval, platelike structures (Figs. 45–46) which may be homologus to the epipharyngeal sclerites described recently by Leidy and Neunzig (1989). These sclerites are more distinct and laterad in *N. gunniella* than in the species of *Dioryctria* figured by Leidy and Neunzig. Like the associated setae, the epipharyngeal sclerites may occur throughout most families of Lepidoptera and have been observed by the senior author in several genera of Psychidae and Tineidae. In all species of Tineinae studied thus far, the outer margins of the epipharyngeal plates are serrated, lateral, and typically project beyond the edge of the labrum.

Host specificity.—A particularly large number of plants were studied including representatives of all taxa closely related to *M. pigra.*

Although newly-emerged larvae fed slightly on a number of plants, the larvae died before completing the first instar. The only established Australian plants which supported development of *N. gunniella* were *M. pigra, M. pudica* and four species of *Neptunia, N. dimorphantha, N. gracilis, N. major* and *N. monosperma.* Larval mortality was lower and plant damage was much more severe on *M. pigra* than on any of these plants.

Any damage to the weed *M. pudica* would be regarded as beneficial in Australia. In Mexico, *N. gunniella* was observed to attack *N. plena* occasionally, but only when this plant was growing in a thicket of *M. pigra* (records of CSIRO Exploratory Unit). Extensive testing of the four *Neptunia* species endemic to Australia, *N. dimorphantha, N. gracilis, N. major* and *N. monosperma,* showed that they may occasionally act as hosts for *N. gunniella* if it was to become established in Australia for biological control of *M. pigra.* However as larval mortality was very high, *N. gunniella* is unlikely to have any significant affect on these *Neptunia* species or to persist on them. Furthermore, the range of *M. pigra* in Australia does not overlap to any significant extent, that of these plants. *N. dimorphantha* and *N. monosperma* are reported from open grasslands in northern and eastern Australia where *M. pigra* does not occur. *N. major* occurs along rivers in northern Australia (Windler 1966) but is uncommon in areas infested with *M. pigra. N. gracilis* is a rare plant on floodplains in the Northern Territory (C. G. Wilson, pers. comm.) and is more common in open grasslands of Queensland and northern New South Wales.

In Mexico the full impact of *N. gunniella* on the growth of *M. pigra* plants was limited by a suite of larval parasitoids. Away from these natural enemies the potential of *N. gunniella* as a biological control agent is estimated to be high. The first release of this insect (100 adults and 1200 eggs) was made at the lower Adelaide River flood plain, 69 km east southeast of Darwin, Northern Territory, Australia on February 2, 1989. Subsequently Napompeth (pers. comm.) reported that in quarantine studies in Thailand, *N. gunniella* fed on *Neptunia oleraceae* Lour., an important aquatic vegetable, and was not approved for release against *M. pigra*.

Acknowledgments

We thank Vichai Malikul and Young Sohn, Department of Entomology, Smithsonian Institution for the line drawings and Susann Braden and Brian Kahn, Smithsonian SEM Lab, and Victor Krantz Smithsonian Photographic Laboratory for photographic assistance. The final draft of the manuscript was prepared by Silver West.

Michael Day, Glynn Maynard and Hugo Miranda provided valuable technical assistance. Parasitoids were kindly identified by E. E. Grissell, P. M. Marsh, C. W. Sabrosky, M. E. Schauff and N. E. Woodley, research entomologists of the Systematic Entomology Laboratory, BBII, USDA. Gail Robertson and Lyall Skilling assisted with illustrations. This study was supported financially by the Australian Centre for International Agricultural Research and the Northern Territory Department of Primary Industry and Fisheries.

Literature Cited

Barnes, W. and J. McDunnough. 1917. Check List of the Lepidoptera of Boreal America. Herald Press, Decatur, Ill. viii + 392 pp.

Braun, A. F. 1924. The frenulum and its retinaculum in the Lepidoptera. Annals of the Entomological Society of America 18(3):L 234–256, pl. 23.

Burkart, A. 1948. Las especies de *Mimosa* de la flora Argentina. Darwiniana 8(1): 9–231.

Busck, A. 1906. Tineid moths from southern Texas, with descriptions of new species. Proceedings U.S. National Museum 30: 721–736.

———. 1934. Microlepidoptera of Cuba. Entomologica Americana 13(4): 151–217.

Common, I. F. B. 1970. Lepidoptera, pp. 765–866. *In* CSIRO, The Insects of Australia. Melbourne University Press, Carlton, Victoria.

Davis, D. R. 1983. Gracillariidae, p. 9. *In* R. W. Hodges et al., eds. Check List of the Lepidoptera of America North of Mexico. E. W. Classey Ltd. and the Wedge Entomological Research Foundation, London.

———. 1984. Gracillariidae, p. 26. *In* J. Heppner, ed. Atlas of Neotropical Lepidoptera. Checklist: Part 1 (Micropterigoidea-Immoidea). Dr. W. Junk Publishers, The Hague, Boston, Lancaster.

———. 1989. Generic revision of the Opostegidae, with a synoptic catalog of the world's species (Lepidoptera: Nepticuloidea). Smithsonian Contributions to Zoology, No. 487. 97 pp., 320 figs., 1 map.

Ely, C. R. 1918. A revision of the North American Gracilariidae [sic] from the standpoint of venation. Proceedings of the Entomological Society of Washington 19(1–4): 29–77.

Hodges, R. W. 1978. Gelechioidea, Cosmopterigidae. Fasc. 6.1, 166 + x pp., pls. 1–6. *In* R. B. Dominick et al. The Moths of North America. E. W. Classey Ltd. & The Wedge Entomological Research Foundation, London.

Kassulke, R. C., K. L. S. Harley, and G. V. Maynard. 1990. Host specificity of *Acanthoscelides quadridentatus* and *A. puniceus* (Col.: Bruchidae) for biological control of *Mimosa pigra* (with preliminary data on their biology). Entomophaga 35: 85–96.

Kleinschmidt, H. E. and R. W. Johnson. 1977. Weeds of Queensland. Queensland Department of Primary Industries. 188 p.

Leidy, N. A. and H. H. Neunzig. 1989. Taxonomic study of the larvae of six eastern North American *Dioryctria* (Lepidoptera: Pyralidae: Phycitinae). Proceedings of the Entomological Society of Washington 91(3): 325–341.

Lonsdale, W. M. and R. Segura. 1987. A demographic study of native and introduced populations of *Mimosa pigra*. Proceedings of the Eighth Australian Weeds Conference 1987, pp. 163–166. *In* Lemerle, D. and A. R. Leys, eds. Weed Society of New South Wales, Haymarket.

McDunnough, J. 1939. Checklist of the Lepidoptera of Canada and the United States of America. Part 2, Microlepidoptera. Memoirs of the Southern California Academy of Sciences 2(1): 1–171.

Meyrick, E. 1912a. Genera Insectorum, Lepidoptera Heterocera (Tineae) Fam. Gracilariadae [sic], Fasc. 128, p. 1–36, 1 col. pl. M. Wytsman, Tervuren, Belgium.

———. 1912b. Lepidopterorum Catalogus. Pars 6, Adelidae, Micropterigidae, Gracilariadae [sic], p. 25–68. W. Junk, Berlin.

Miller, I. L. 1982. The distribution and threat of *Mimosa pigra* in Australia, pp. 38–50. *In* G. Lamar Robert and D. H. Habeck, eds. Proceedings of the International Symposium on *Mimosa pigra* Management, Chiang Mai.

Miller, I. L. and W. M. Lonsdale. 1987. Early records of *Mimosa pigra* in the Northern Territory. Plant Protection Quarterly 2: 140–142.

Miller, I. L., L. Nemestothy, and S. E. Pickering. 1981. *Mimosa pigra* in the Northern Territory. Technical Bulletin No. 51, Department of Primary Production, Northern Territory.

Napompeth, B. 1982. Background, threat, and distribution of *Mimosa pigra* L. in Thailand, pp. 15–26. *In* G. Lamar Robert, D. H. Habeck, eds. Proceedings of the International Symposium on *Mimosa pigra* Management, Chiang Mai.

Pitt, J. L. and I. L. Miller. 1989. A review of survey techniques for the detection of weeds with particular reference to *Mimosa pigra* L. in Australia and Thailand. Plant Protection Quarterly 3: 149–155.

Sabrosky, C. W. 1950. A synopsis of the chloropid genera *Chaetochlorops* and *Eugaurax* (Diptera). Journal of the Washington Academy of Sciences 40(6): 183–188.

Tillyard, R. J. 1918. The Panorpoid complex. Part 1. The wing-coupling apparatus, with special reference to the Lepidoptera. Proceedings of the Linnaean Society of New South Wales 53:286–319.

Turner, B. L. 1959. The Legumes of Texas. University of Texas Press, Austin and London. 284 pp.

Vari, L. 1961. South African Lepidoptera, Vol. 1, Lithocolletidae. Transvaal Museum, Memoir No. 12, xix + 238 pp., 112 pls.

Windler, D. R. 1966. A revision of the genus *Neptunia* (Leguminosae). Australian Journal of Botany 14: 379–420.